



GSFC • 2015

Correlation of the SAGE III on ISS Sensor Assembly Thermal Model to Thermal Vacuum Testing

Ruth M. Amundsen
NASA Langley Research Center

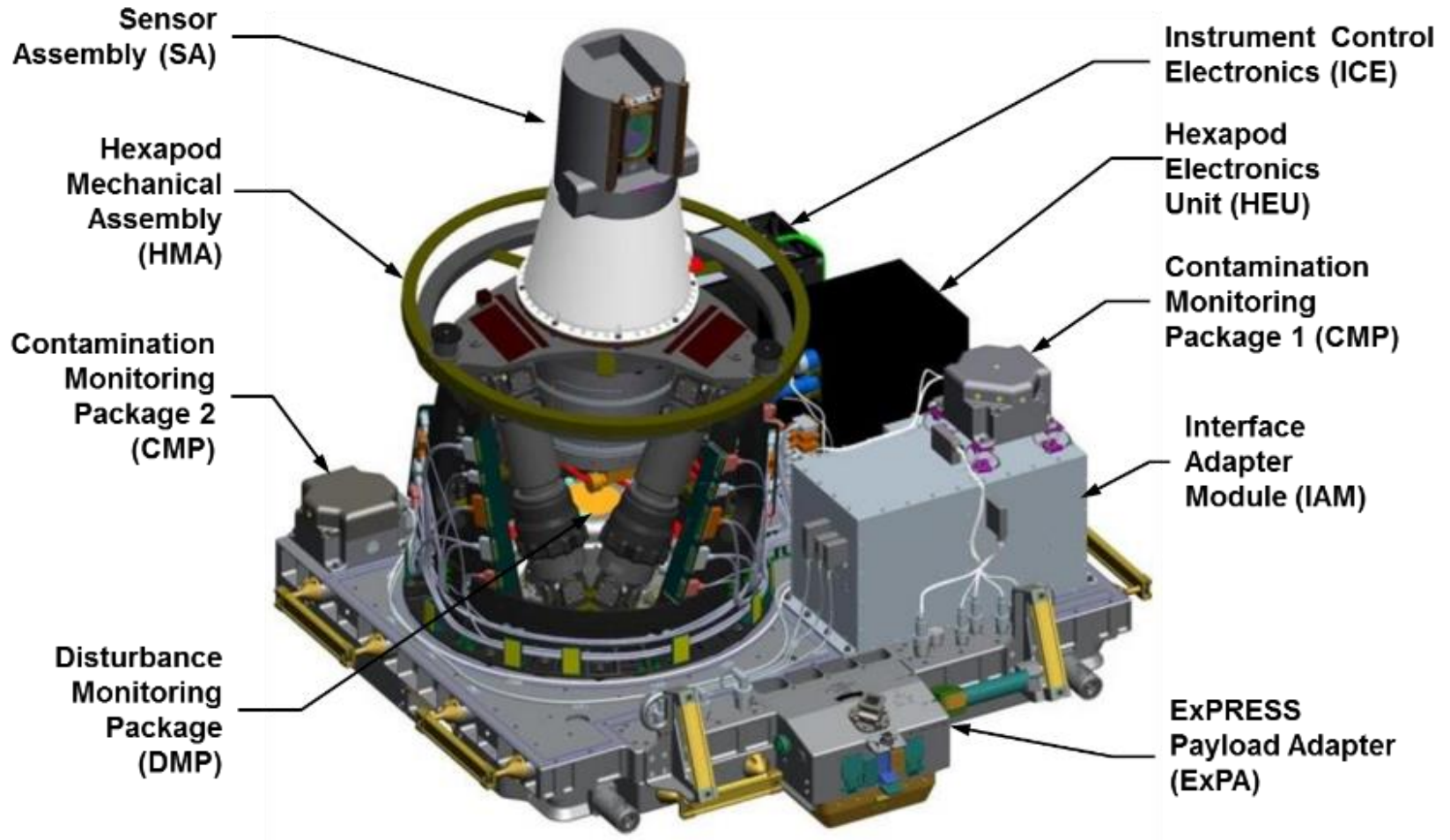


Agenda

- Background
- SAGE III thermal model
- Sensor assembly
- TVAC test setup
- Model complexities
- Thermal model correlation
- Conclusion



SAGE III Instrument Payload





Launch on SpaceX

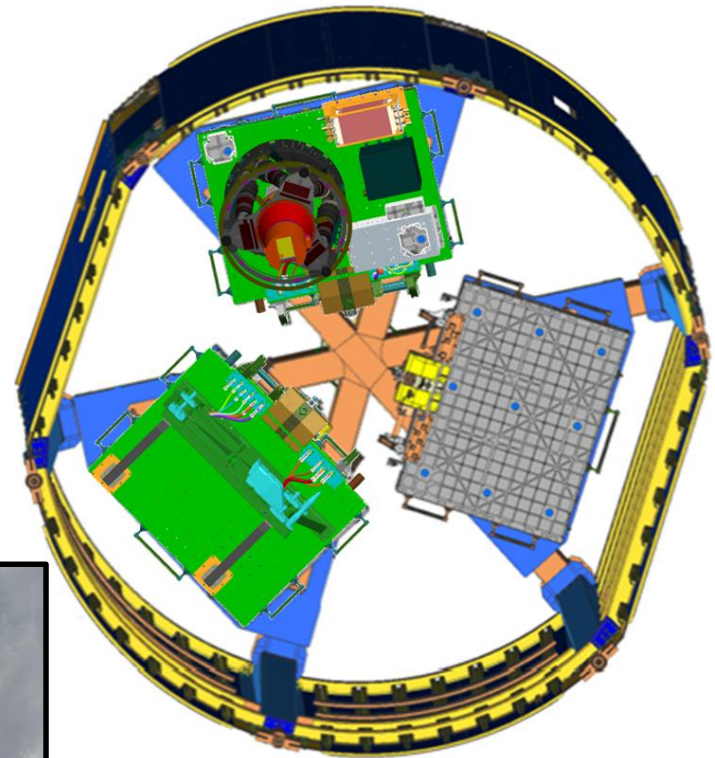
Falcon 9



Integration Hangar



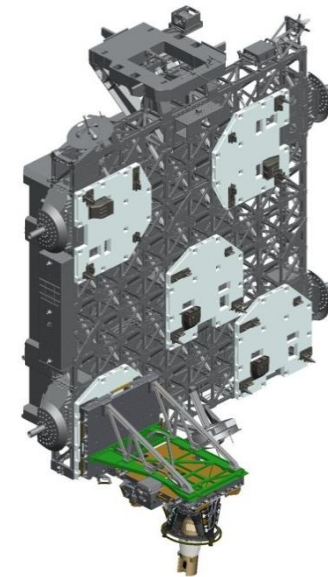
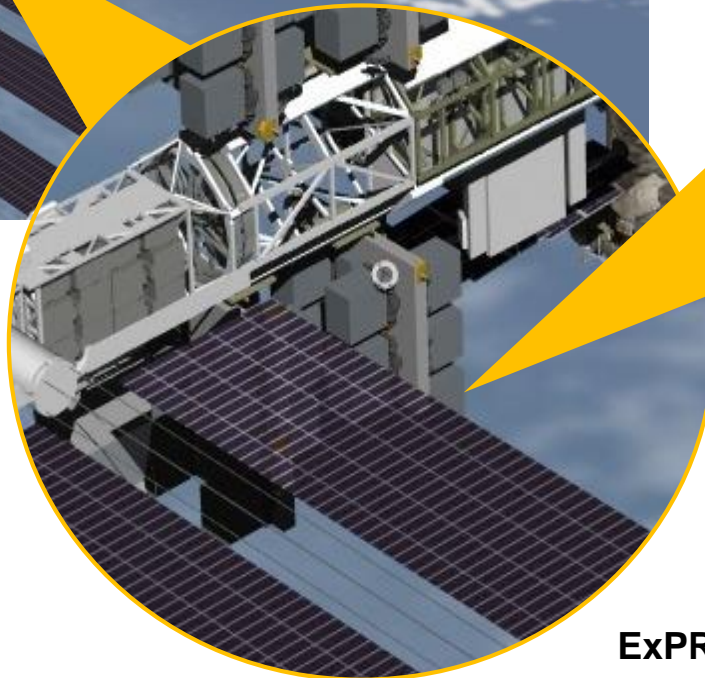
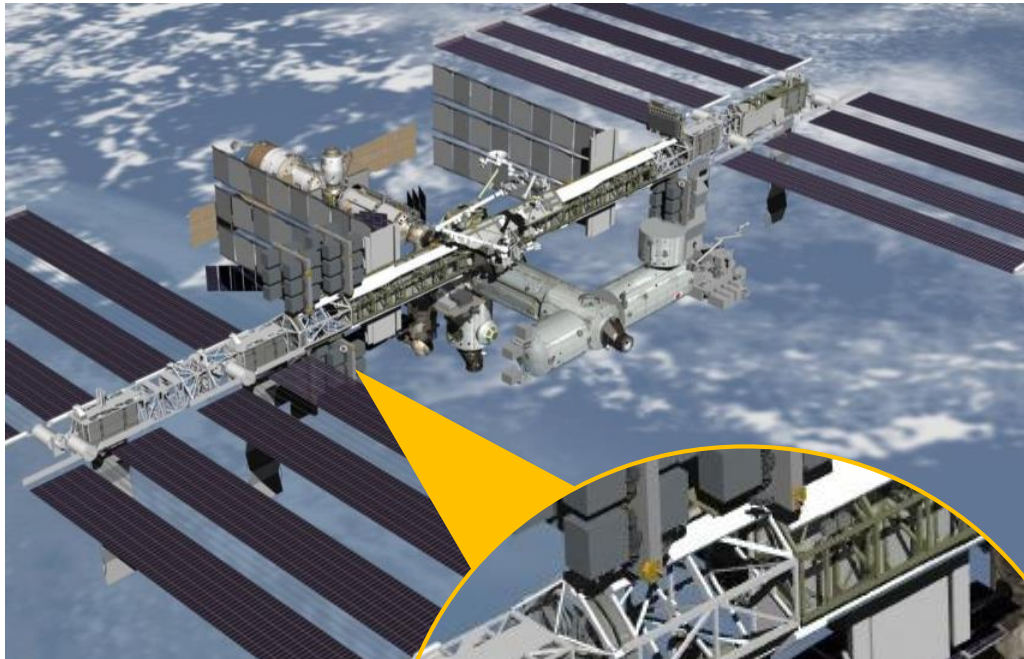
**Dragon Unpressurized
Cargo Module**





SAGE III on ISS

S3 Truss Payload Attachment System-4 Site (PAS-4)

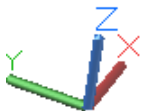
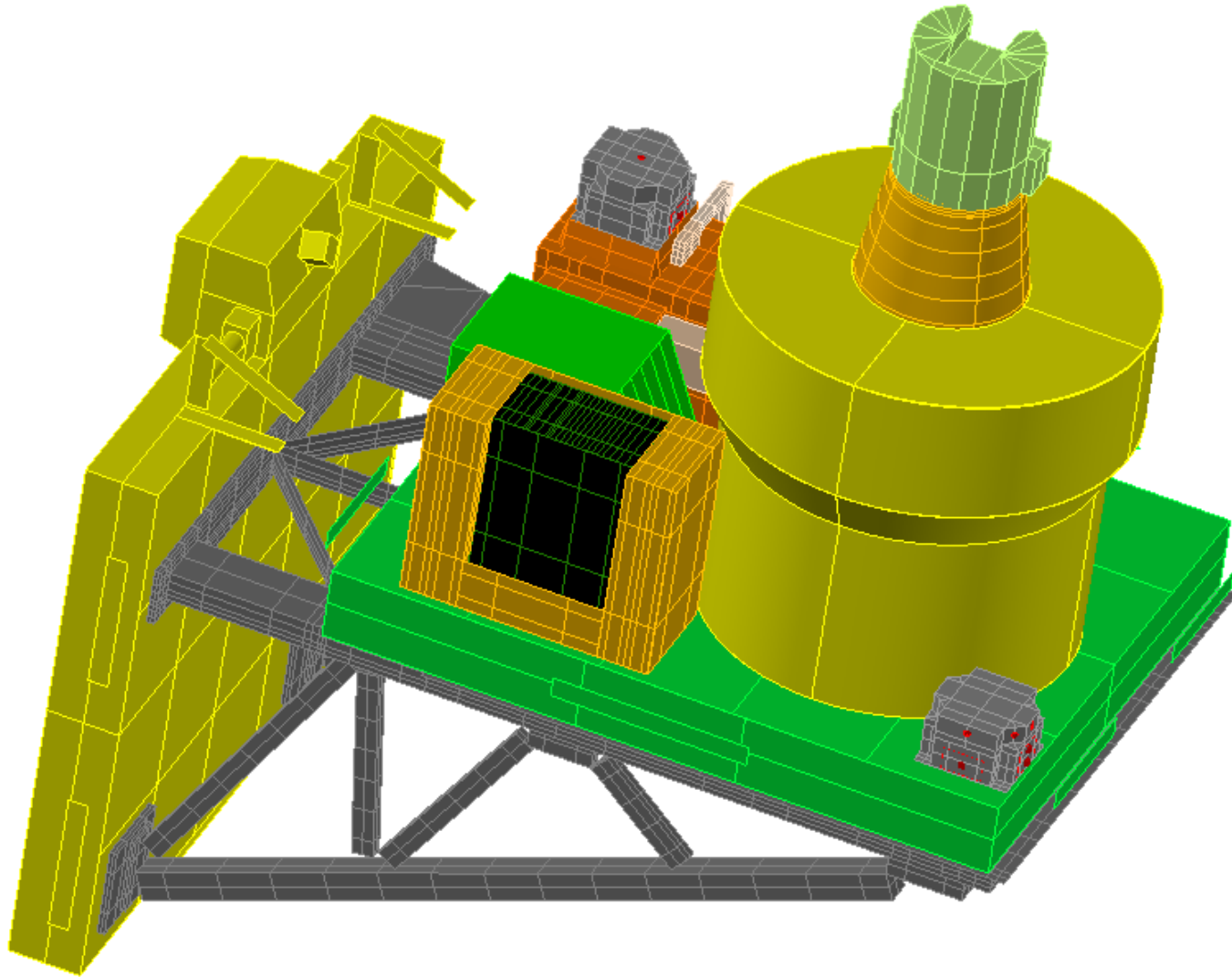


Passive FRAM Adapter Plate Site 3 (PFAP-3)

ExPRESS Logistics Carrier-4 (ELC-4)



SAGE III Thermal Model





Heritage Flight Hardware

- SAGE III has been maintained at NASA LaRC
- Hexapod has been maintained at Thales Alenia Space – Italia (TAS-I) in Turin, Italy
- Hardware is >20 years old



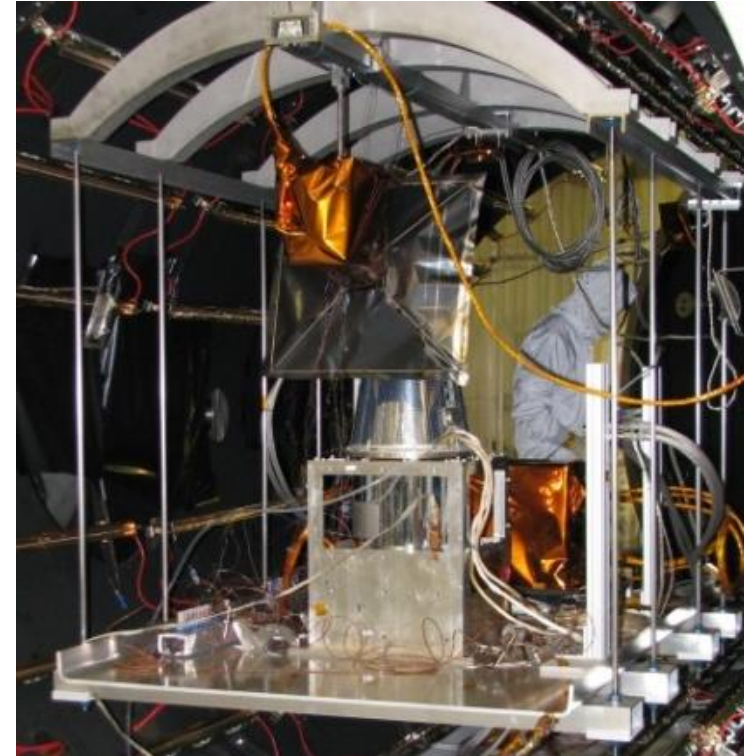
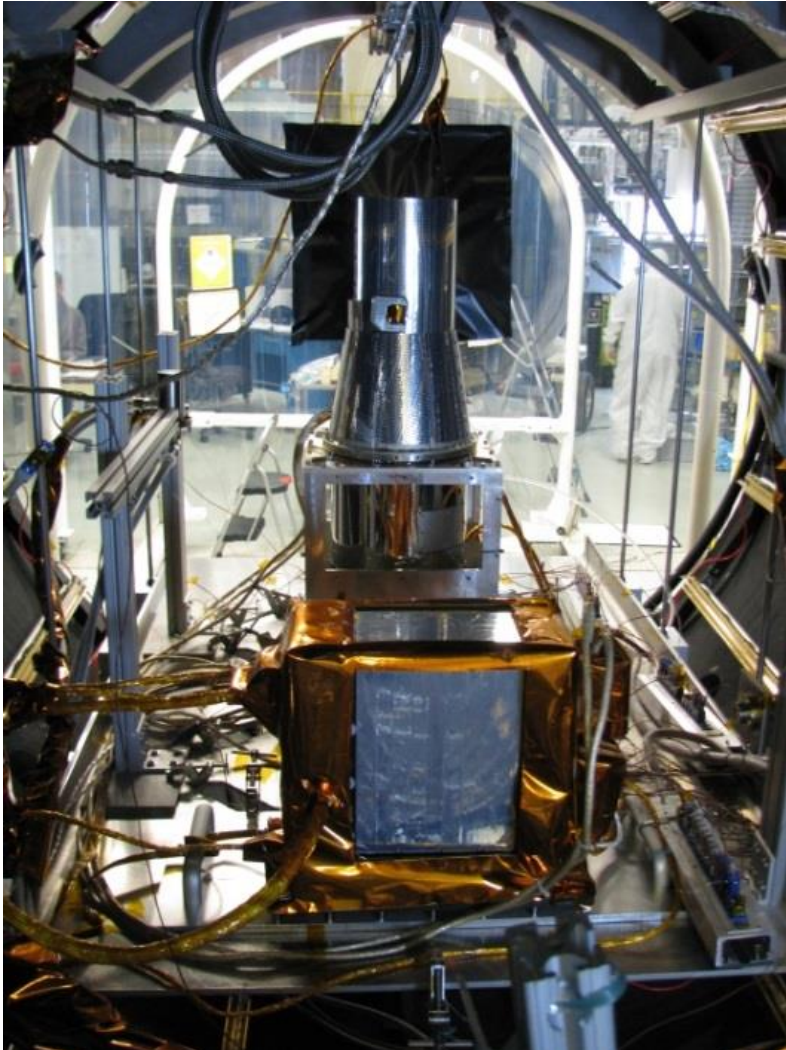
Sage III Instrument



Hexapod Pointing System



8x15' Thermal Vacuum Chamber



- Instrument TVAC testing at LaRC
- Nov 2014 – March 2015
- Unpowered, heater-only, and powered balances, hot and cold



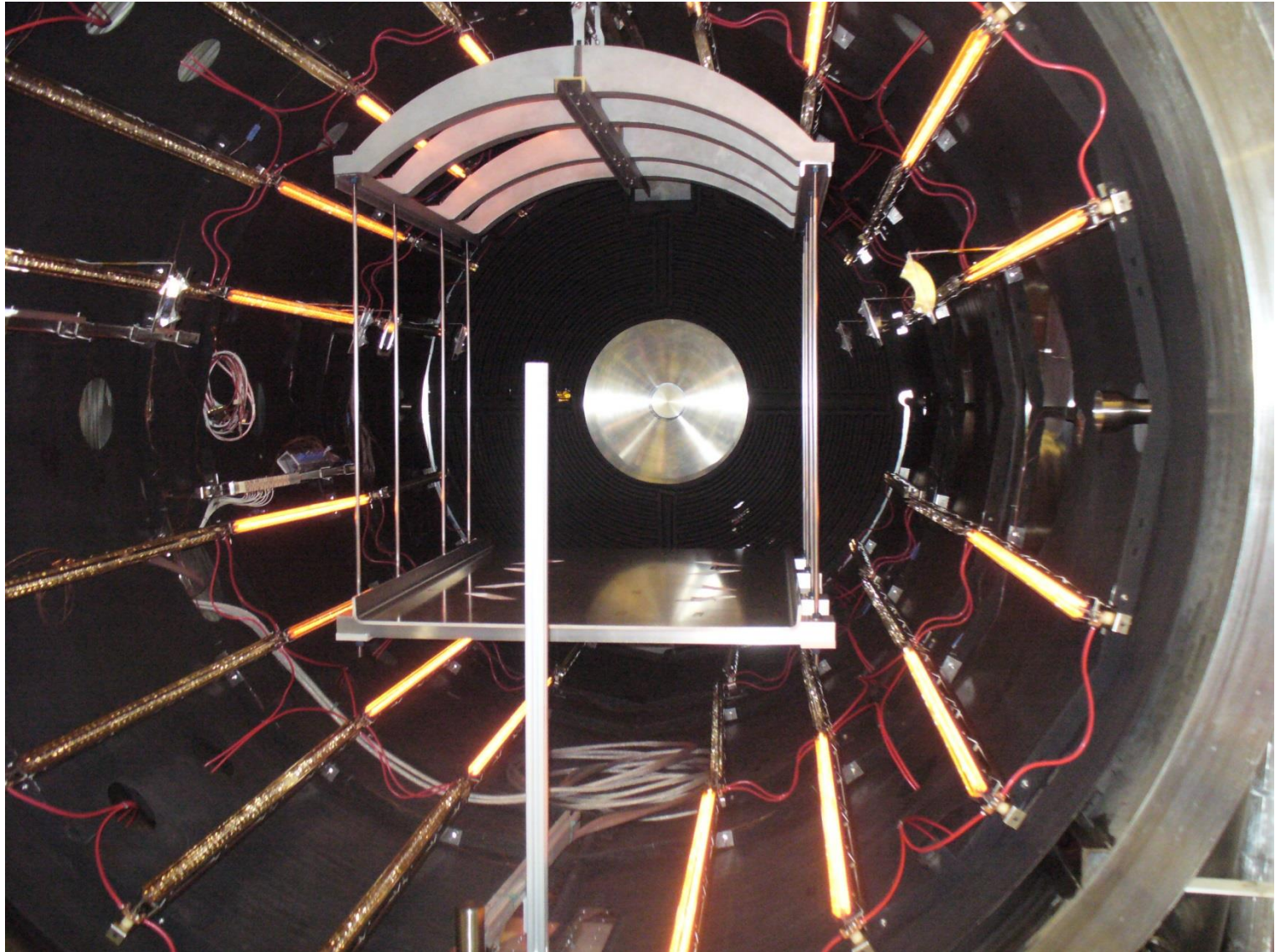
Thermal Model Complexities

- Heritage hardware
- Lamps in TVAC
- Thermo-electric cooler
- Elevation motor power





“IR” Lamps in TVAC



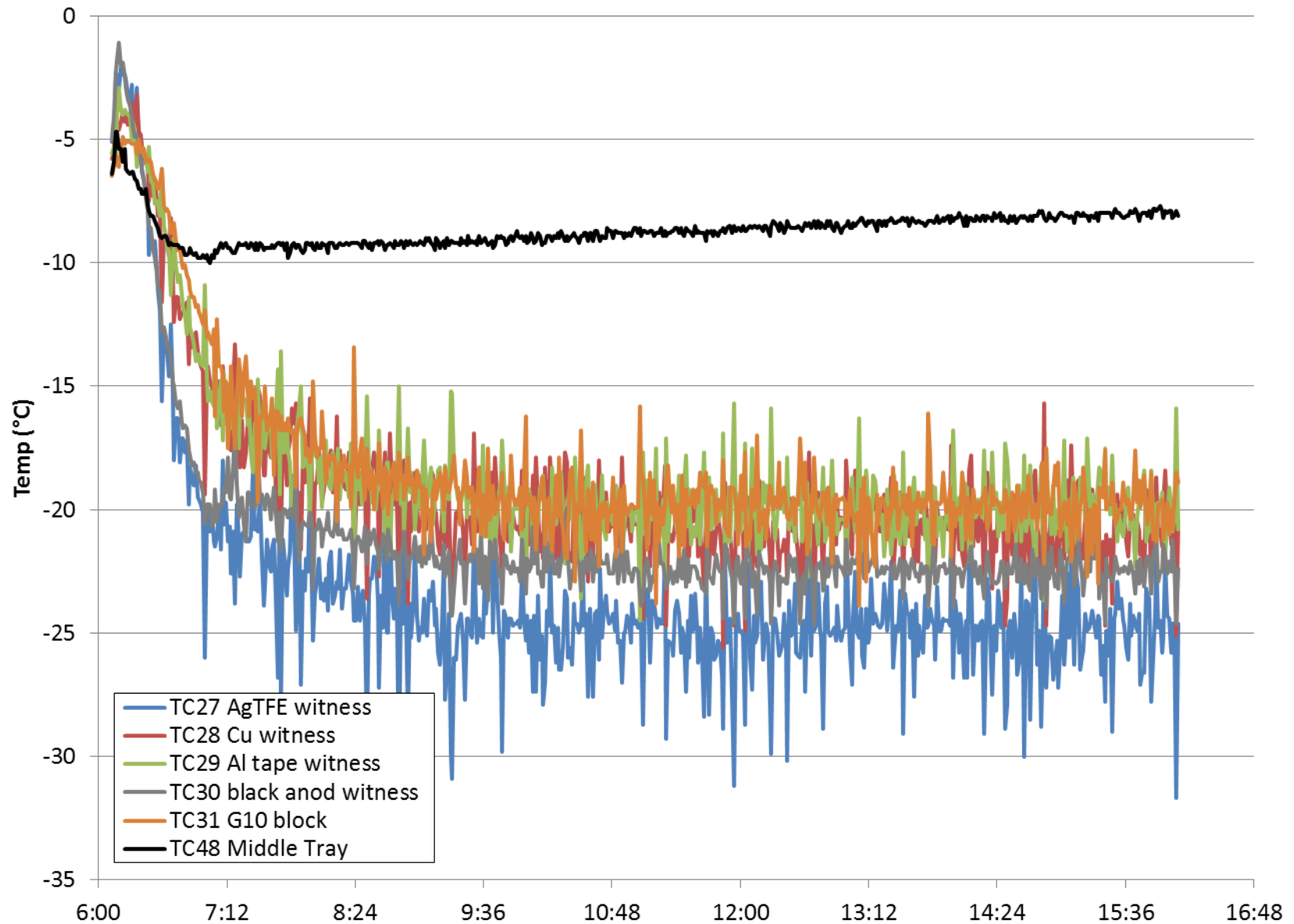


Lamp Issues

- Control noise
- Lack of stable power measurement
- Solar spectrum fraction varies with voltage
 - Difficult to run transient with changing chamber environment
 - Radks must be run in solar as well as IR
 - Rays shot from each lamp bank in separate radk case
 - Difficult to determine solar fraction
 - Some TVAC surfaces had no measured solar alpha

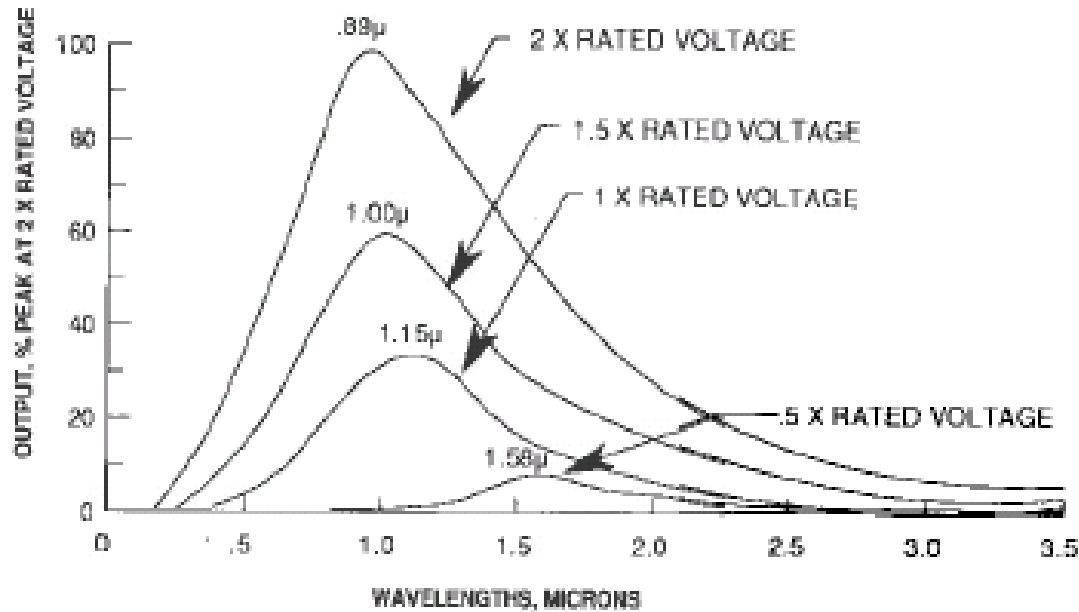


Thermal Noise due to Lamp Control





Solar Spectrum of Lamps



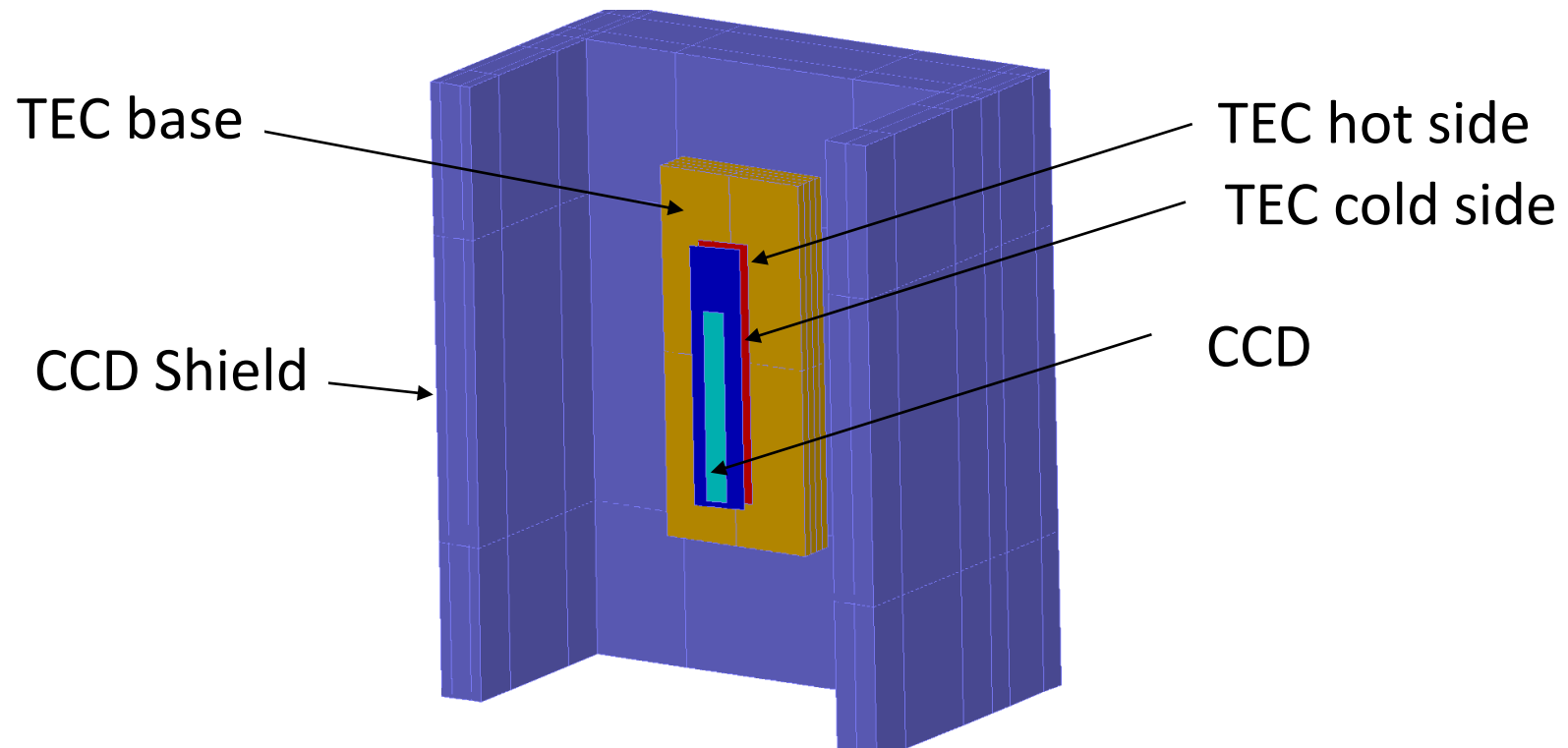
POWER DISSIPATION VS. VOLTAGE FORMULA

$$\frac{w}{W} = \left(\frac{v}{V} \right)^{1.54}$$

w = Power Dissipated, Watts
 W = Rated Power, Watts
 v = Lamp Voltage, Actual
 V = Lamp Voltage, Rated



Thermo-electric Cooler





TEC Implementation in TD

TEC

Enabled...

Comment: **CCD TEC**

Conductor Submodel: **SAGE_INSTRUMENT**

Register append string: **_TEC**

Input Parameters

Input Mode: **Power**

Power: **10.2364** BTU/hr

Area/Thickness Per Couple: **0.00219816** ft

☒ Bismuth Telluride

Num Couples: **15**

☐ User Defined

Seebeck Coeff: **0** Volts/C

Eff. Resistivity: **0** ohm-ft

Conductivity: **0** BTU/hr/ft/C

☒ Generate Conductors For Couples

☐ Use Deep Solution Method

Control Parameters

Control Side: **Cold Side**

On Temp: **25** C

Off Temp: **23** C

☒ Proportional **Sense Method...**

Steady State

☒ Percentage of Input

Percentage: **40** %

☐ Set to Mid Point Temperature
(Caution should be used with this option, this use of boundary nodes can result in non-sensical results)

Offset Temp: **-1** C

Cold Side(1):
Rect-SA: TEC cold side[SAGE_INSTRUMENT]::28355 Bottom

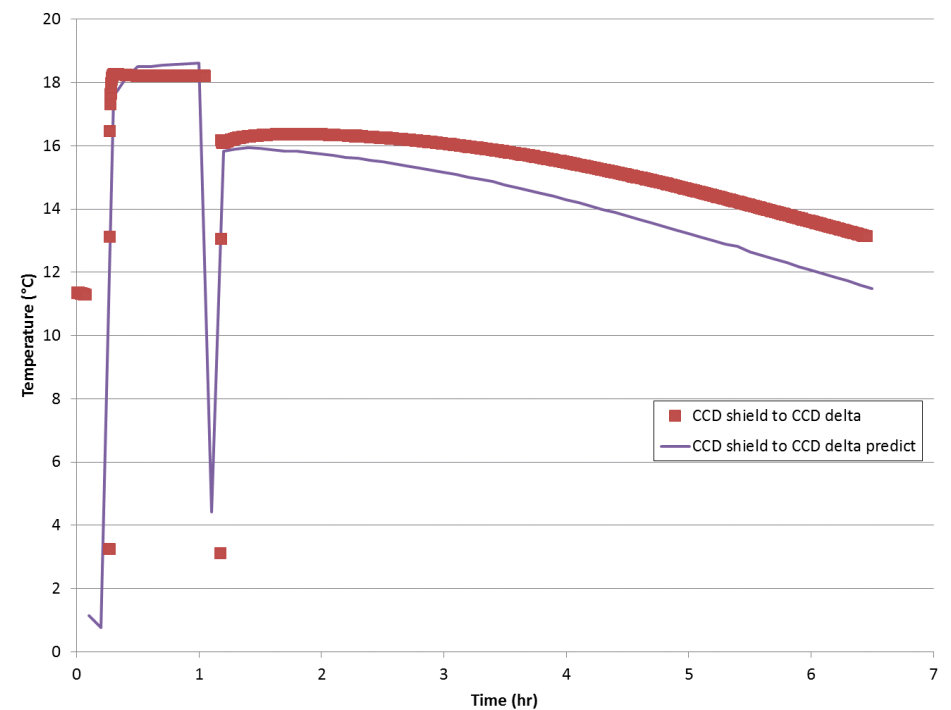
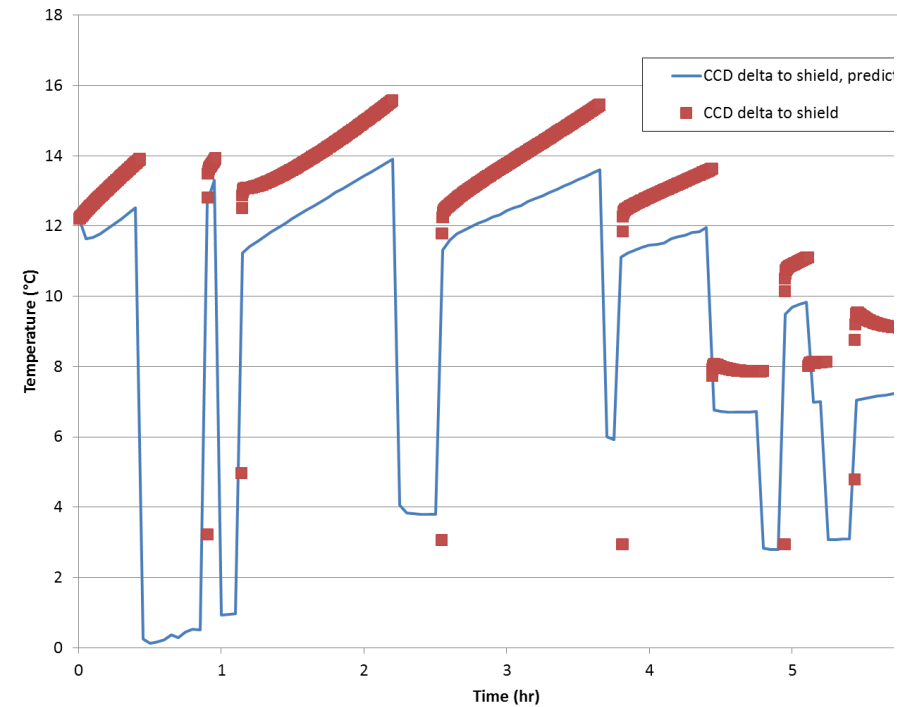
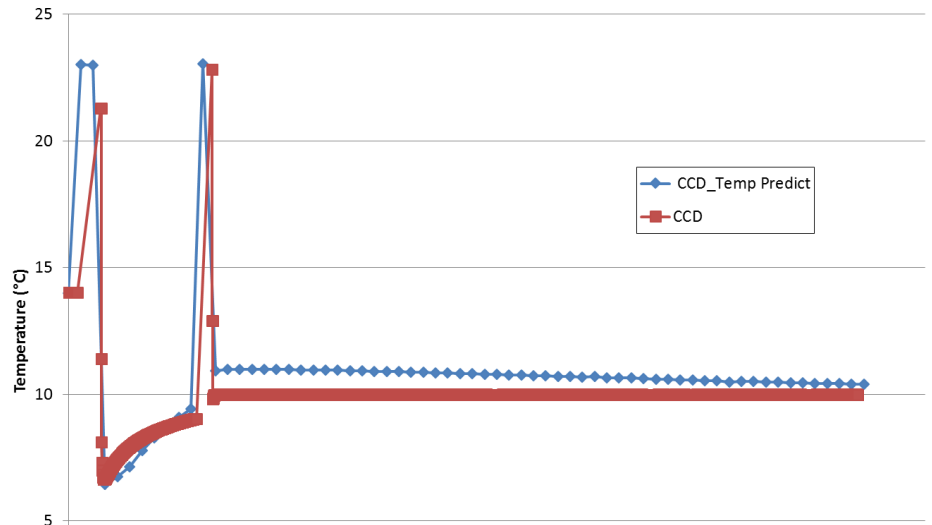
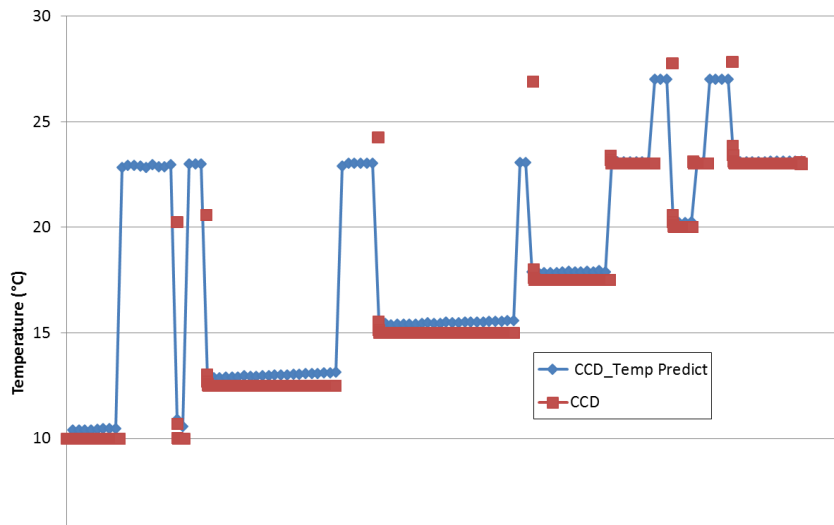
Hot Side(1):
Rect-SA: TEC hot side[SAGE_INSTRUMENT]::28357 Top

OK Cancel Help

- Test data showed TEC held delta of 18°C (original spec >50°C)
- Back conductor used to account for TEC degradation
- Symbols used for all control variables to allow parametric runs
- Four cases with TEC setpoint changes used for correlation

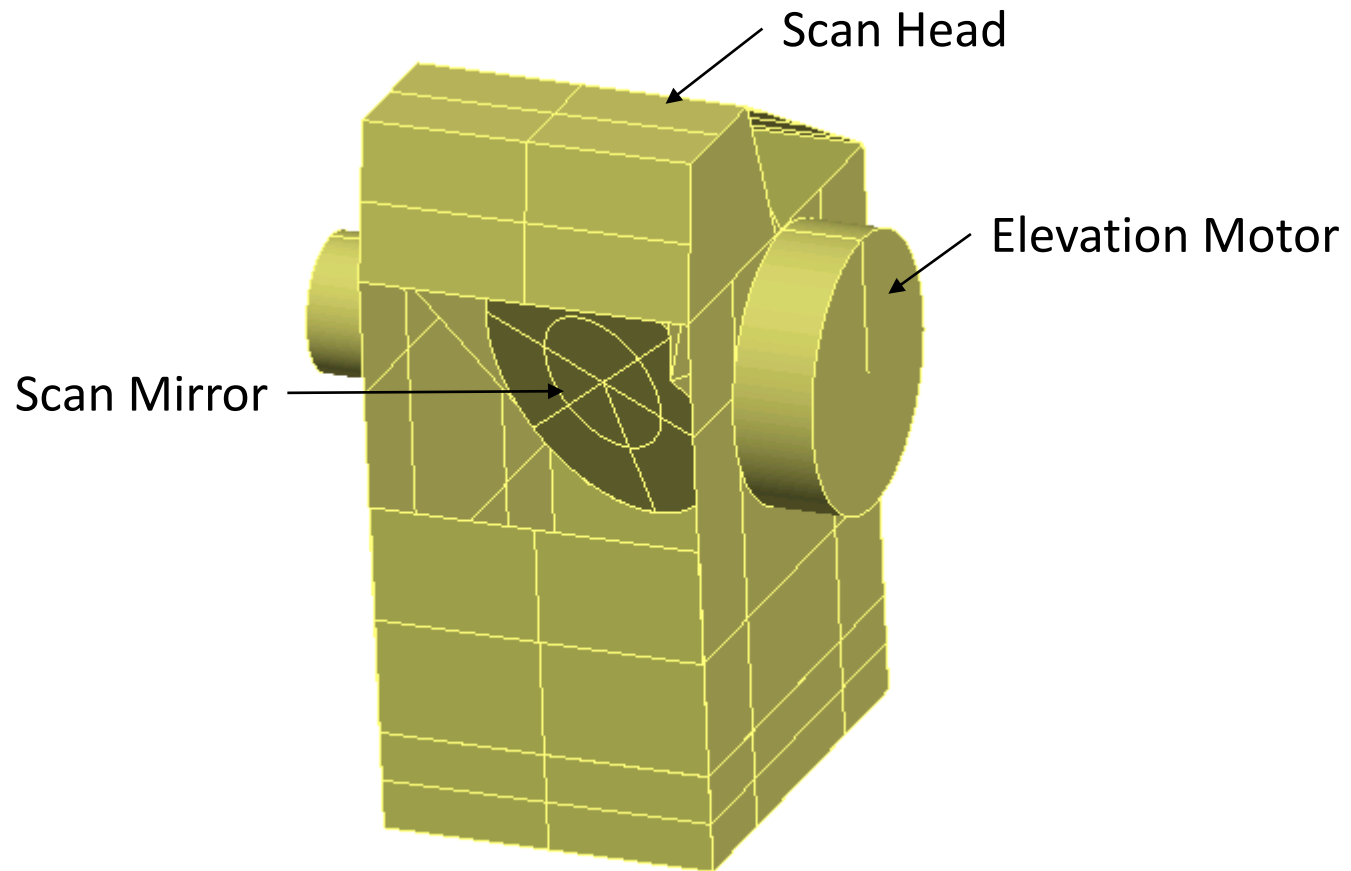


TEC Correlation



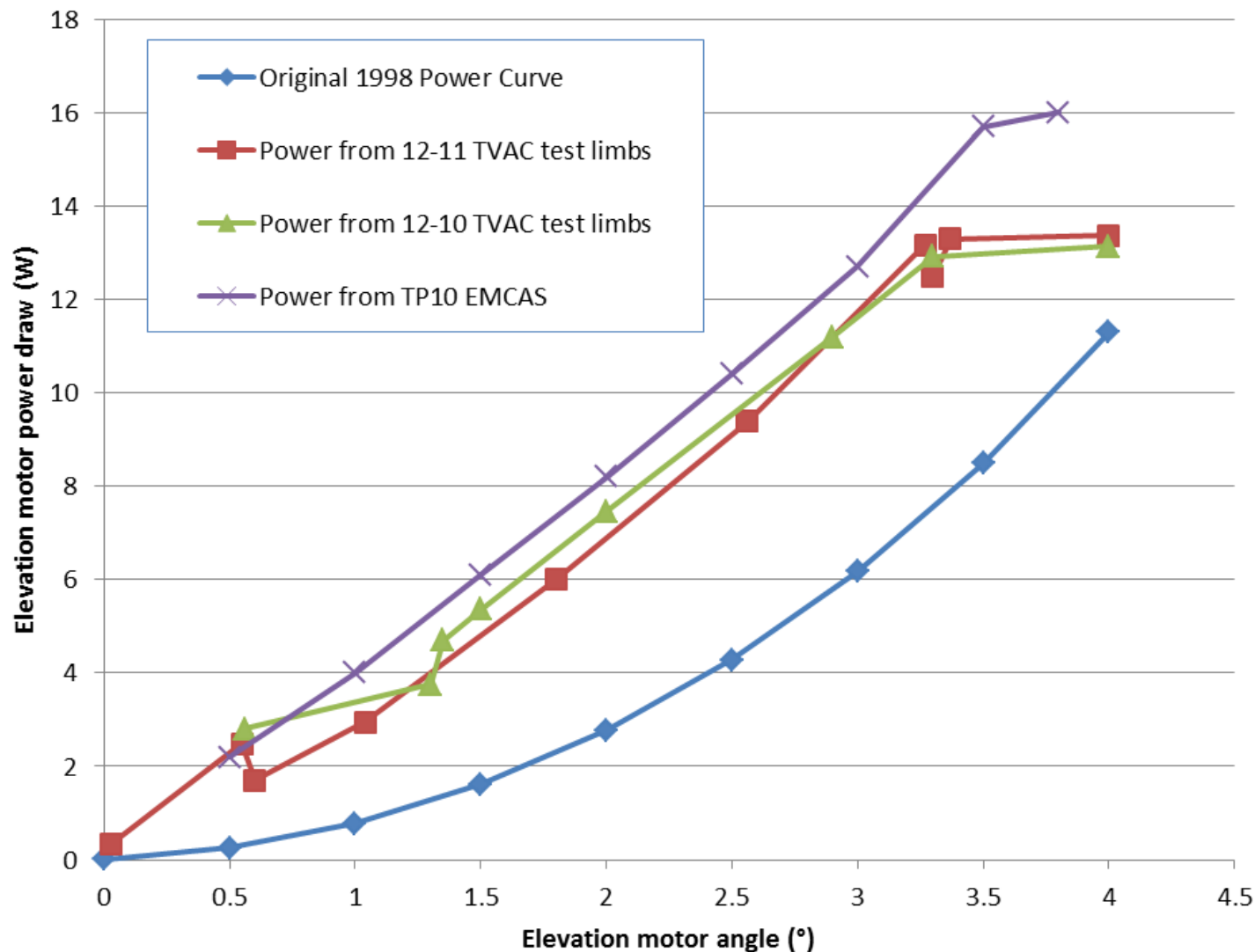


Elevation Motor



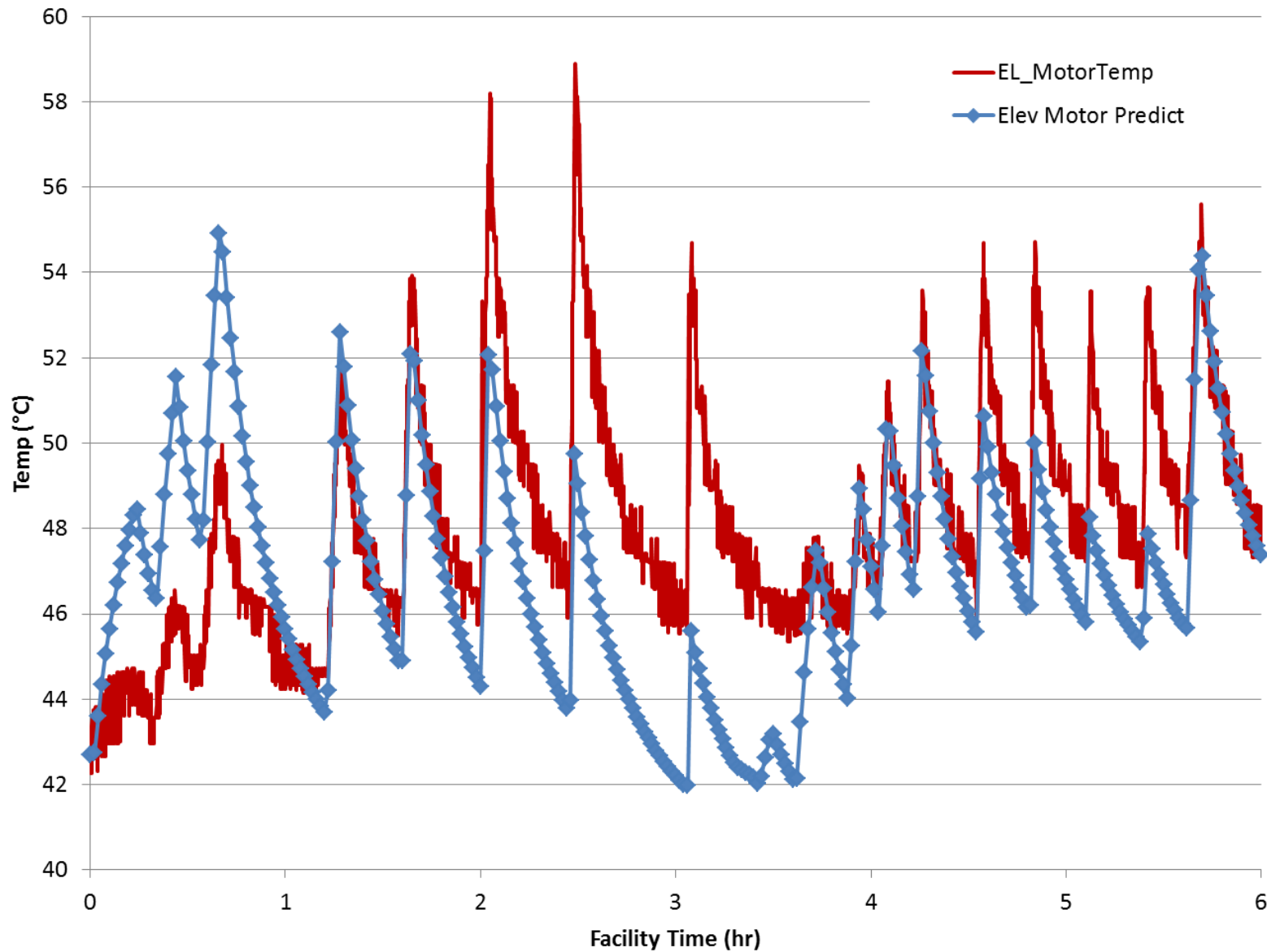


Elevation Motor Power – Initial Measurements



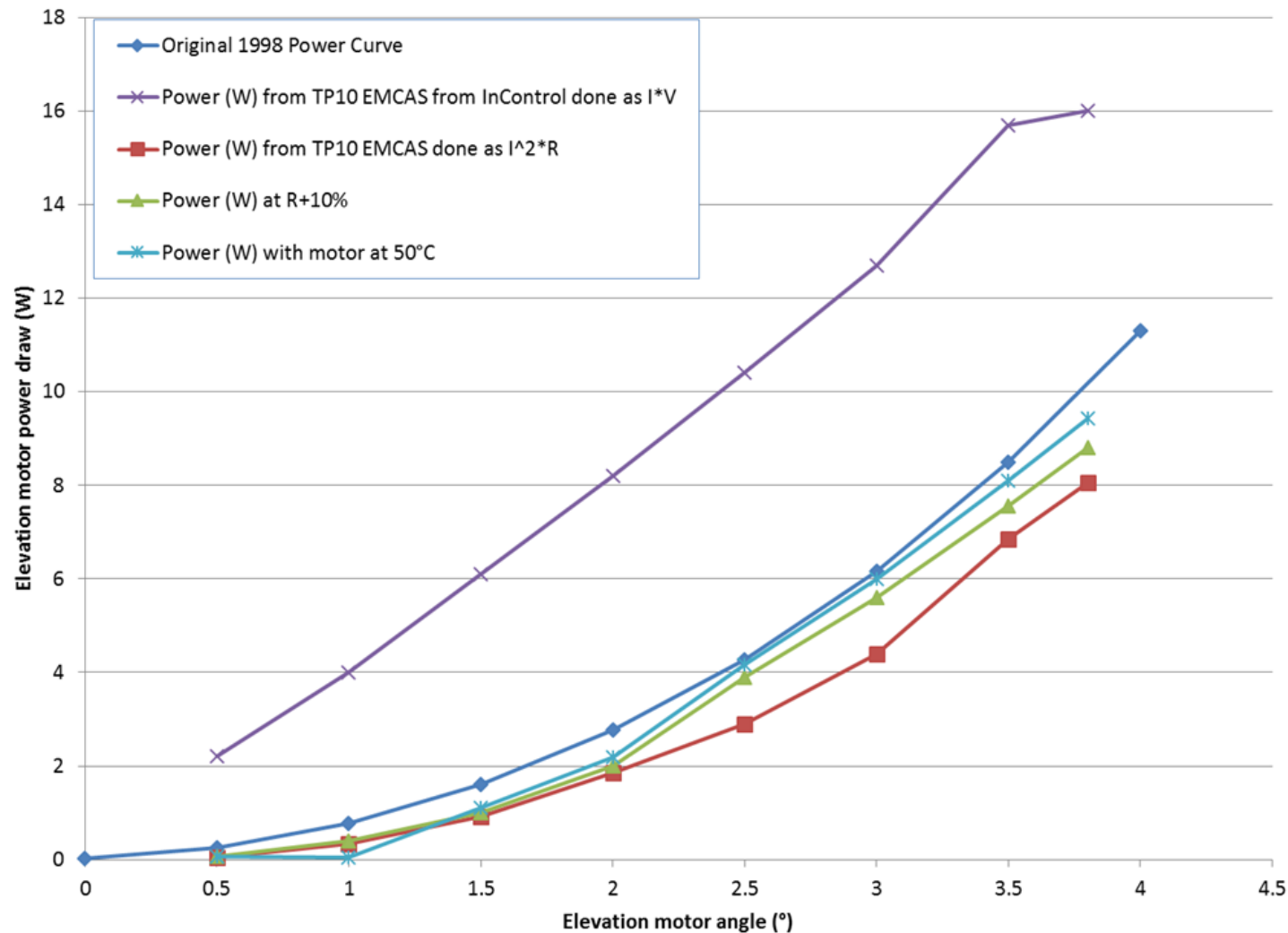


Initial Correlation to Elevation Motor Events





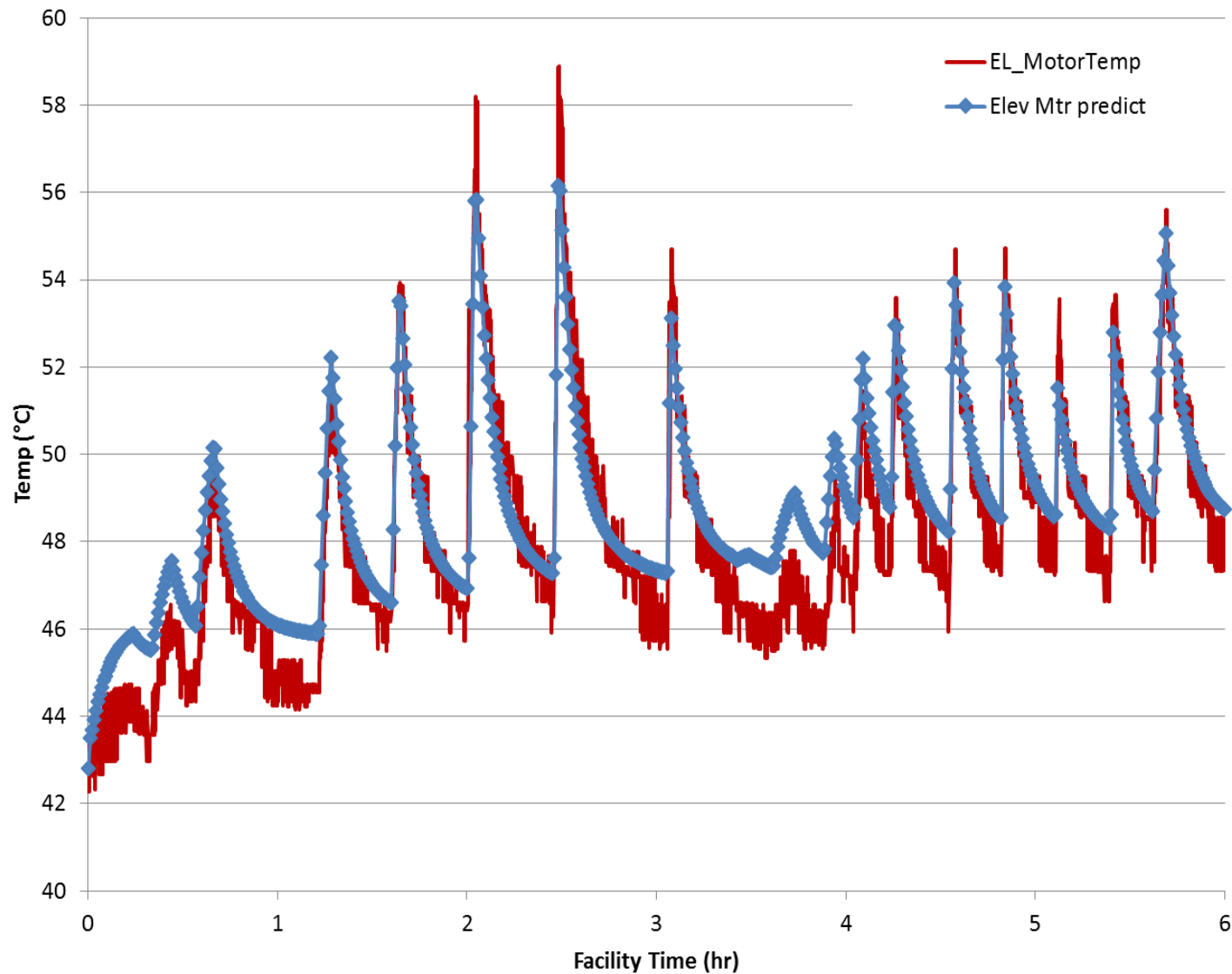
Elevation Motor Power - Actual



- This is a case where $\text{Power} \neq I \cdot V$ (instead, $P = I^2 R$)

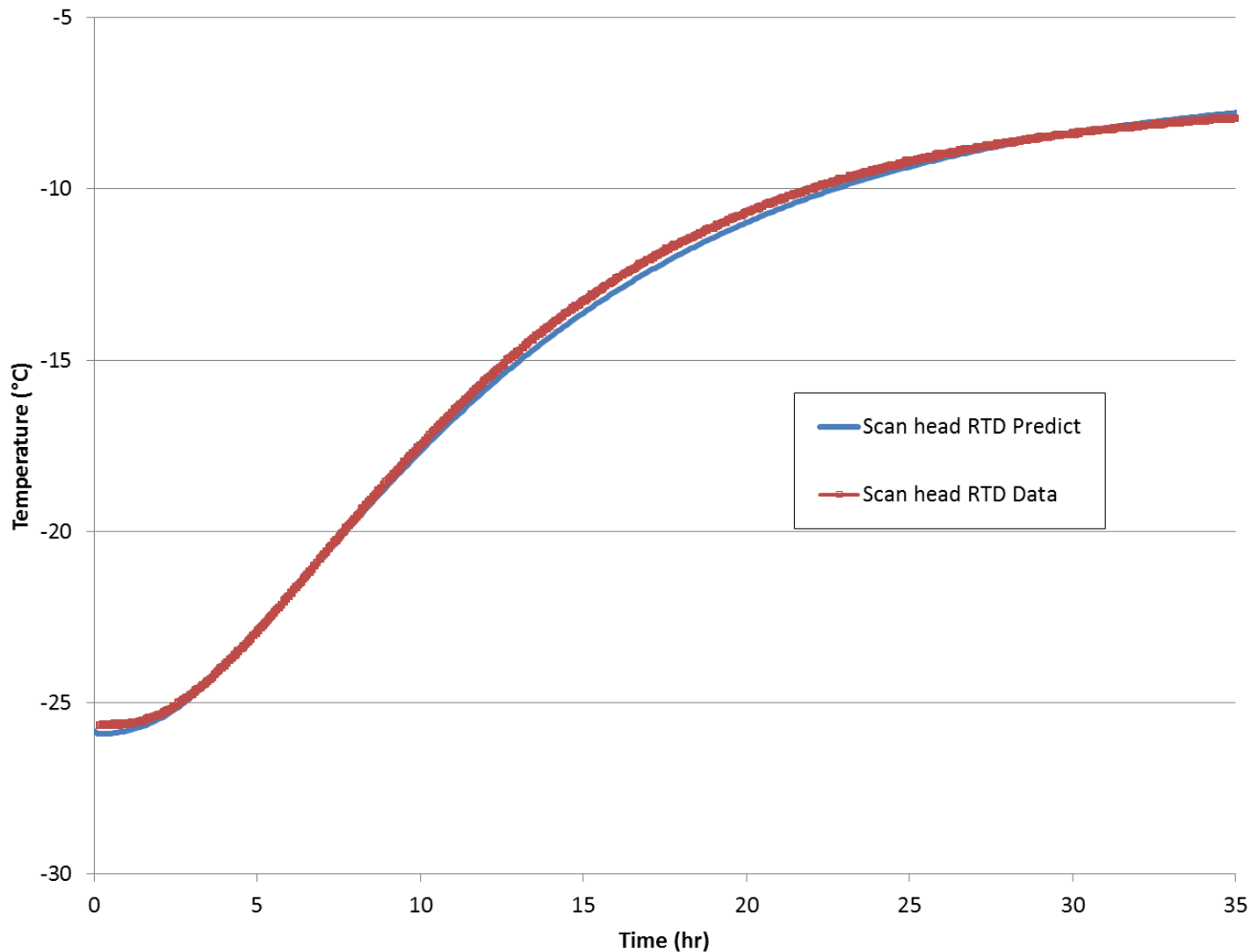


Final Correlation to Elevation Motor Events



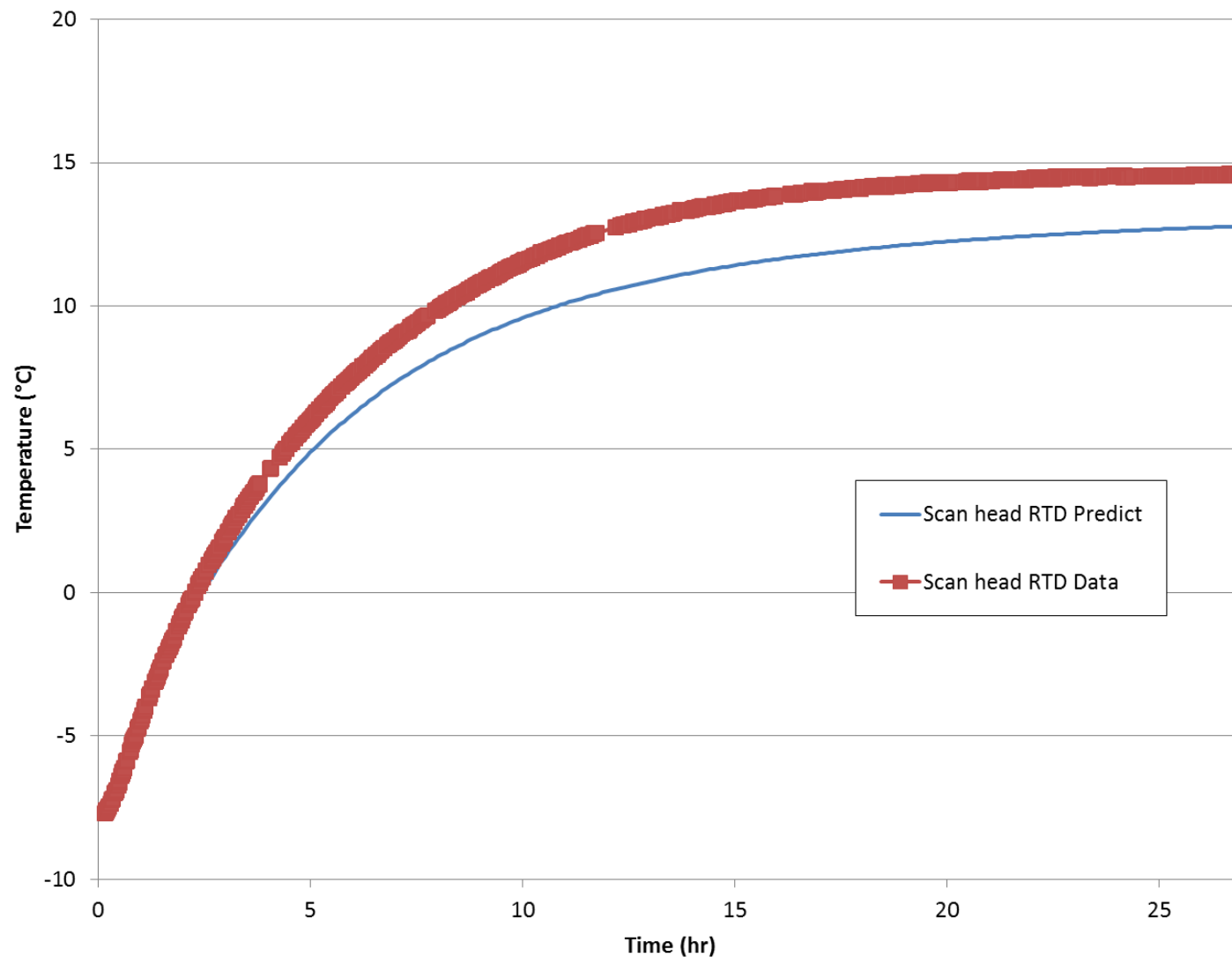


Example of Heater-Only Balance Transient



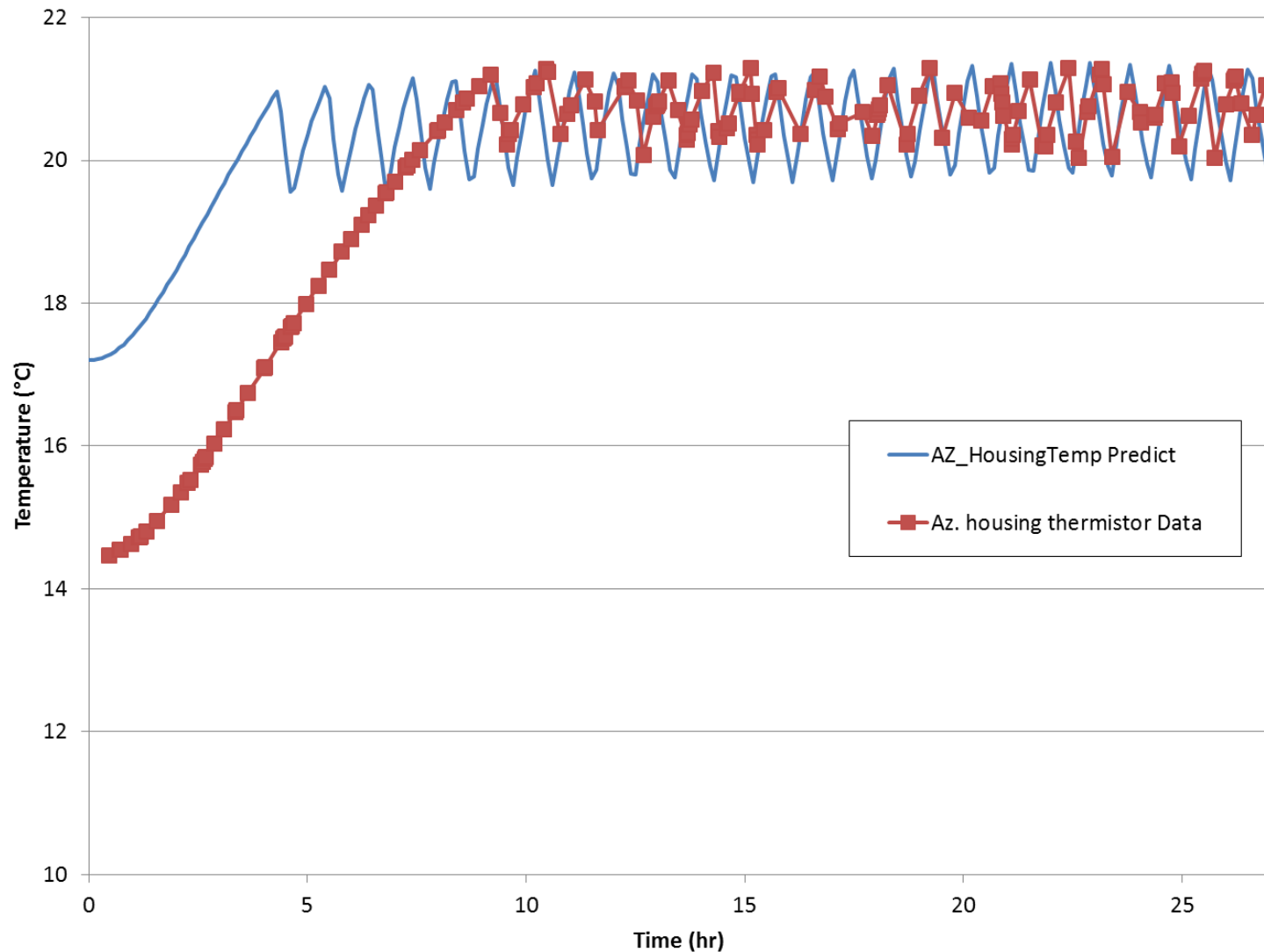


Example Powered Transient to Cold Balance



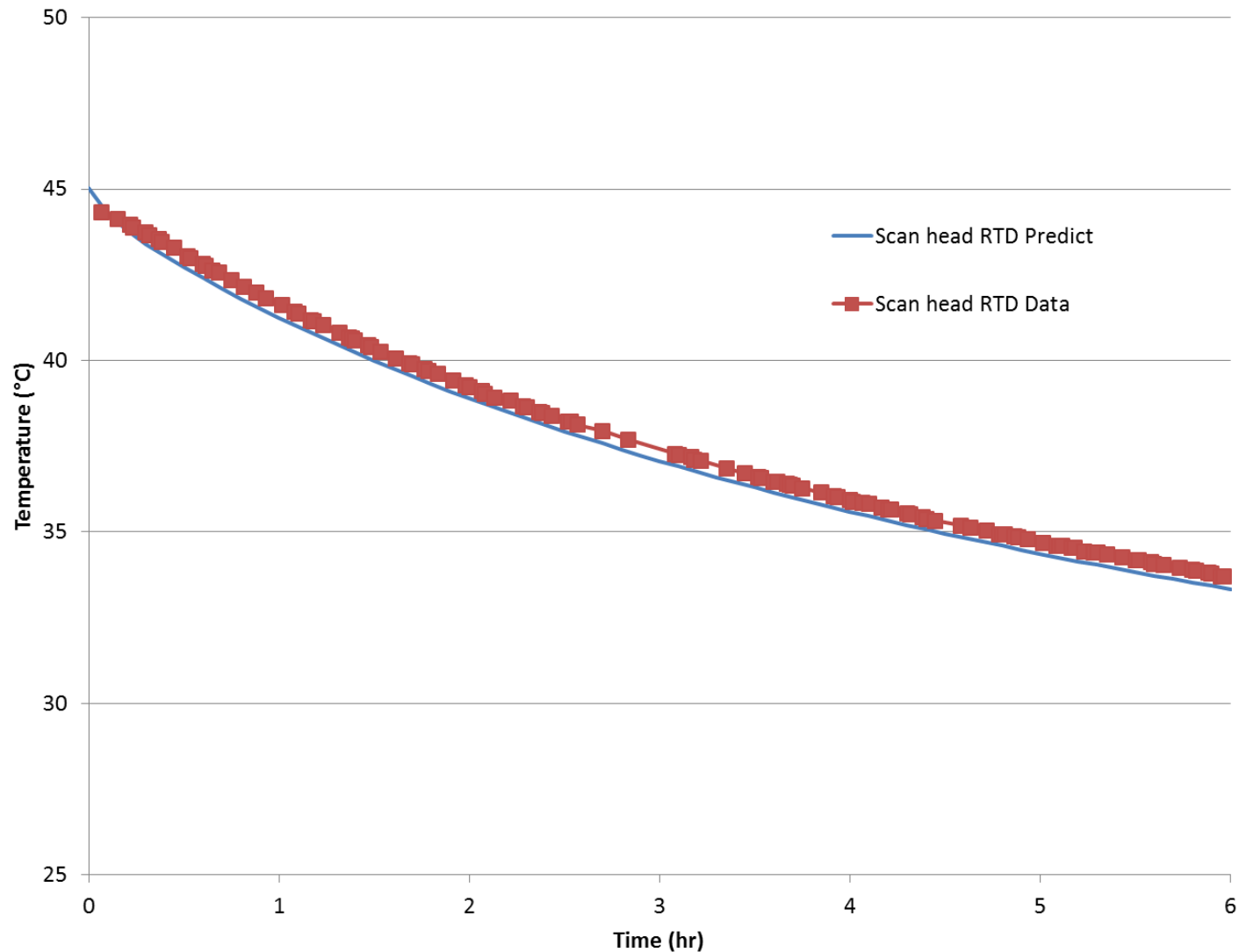


Example Correlation of Heater-Controlled Part





Example Unpowered Cooldown Correlation





Summary Correlation Results

	Hot powered transient	Hot cooldown	Cold powered transient	Cold cooldown	Overall error
Overall RMS error (°C)	1.4	0.5	2.7	1	1.4
Avg error (°C)	-0.2	0.2	0.9	-0.6	0.1
Flight sensor RMS error (°C)	1.5	0.5	1.6	1.2	1.2

RMS error calculated over all sensors, entire transient timeline



Conclusions

- Quartz “IR” lamps in TVAC make correlation difficult
- TD implementation of TEC effective
- Power not always $I \cdot V$, depending on component
- Heritage hardware/model feasible to correlate well
- Heater-only balance extremely useful in correlation
- Unpowered cooldown extremely useful in correlation



Backup



Major Model Changes in Correlation

- Measured solar α for TVAC aluminum/steel parts
- Emissivity and ε^* for crushed MLI
- Motor powers
- TEC power and back-conductor
- Solar lamp fraction
- TVAC shroud temperatures
- Contact for GSE hardware to TVAC tray
- Mass factors for cabling
- Heater control location
- Scan head position

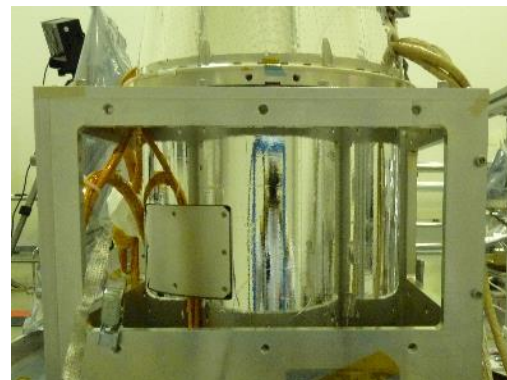


Sensor Assembly Hardware

Scan head and
azimuth
assemblies
covered in
perforated silver
Teflon

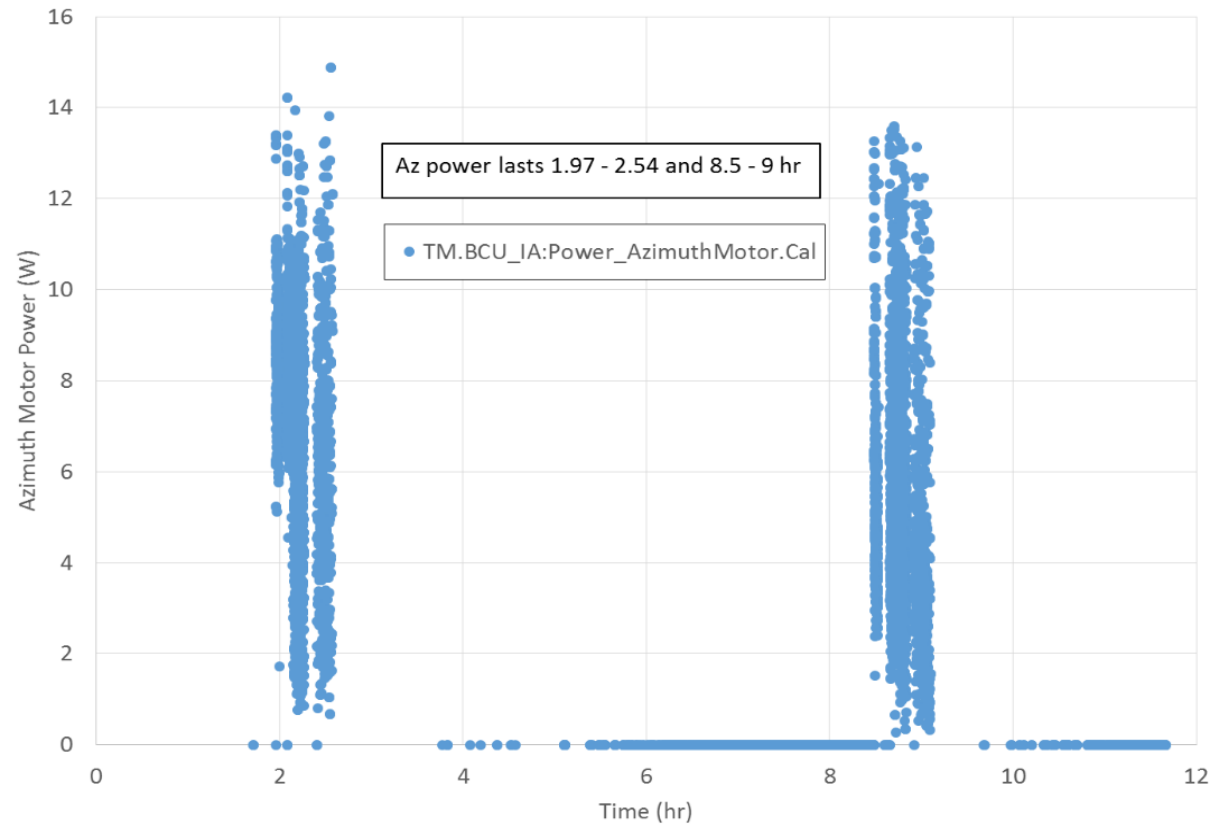


Spectrometer
thermal shroud
covered in
aluminized Kapton
(SA is mounted in
a GSE fixture for
testing)



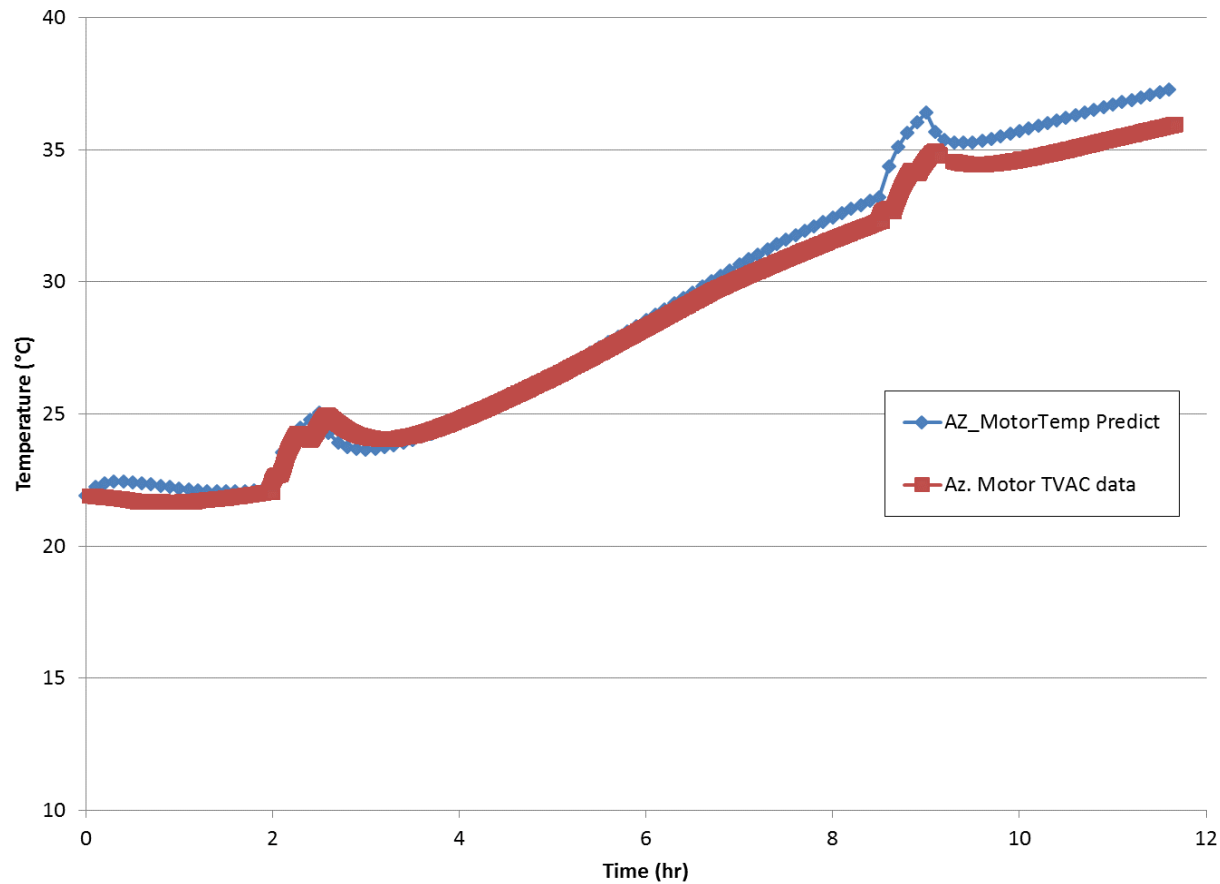


Azimuth Motor Power



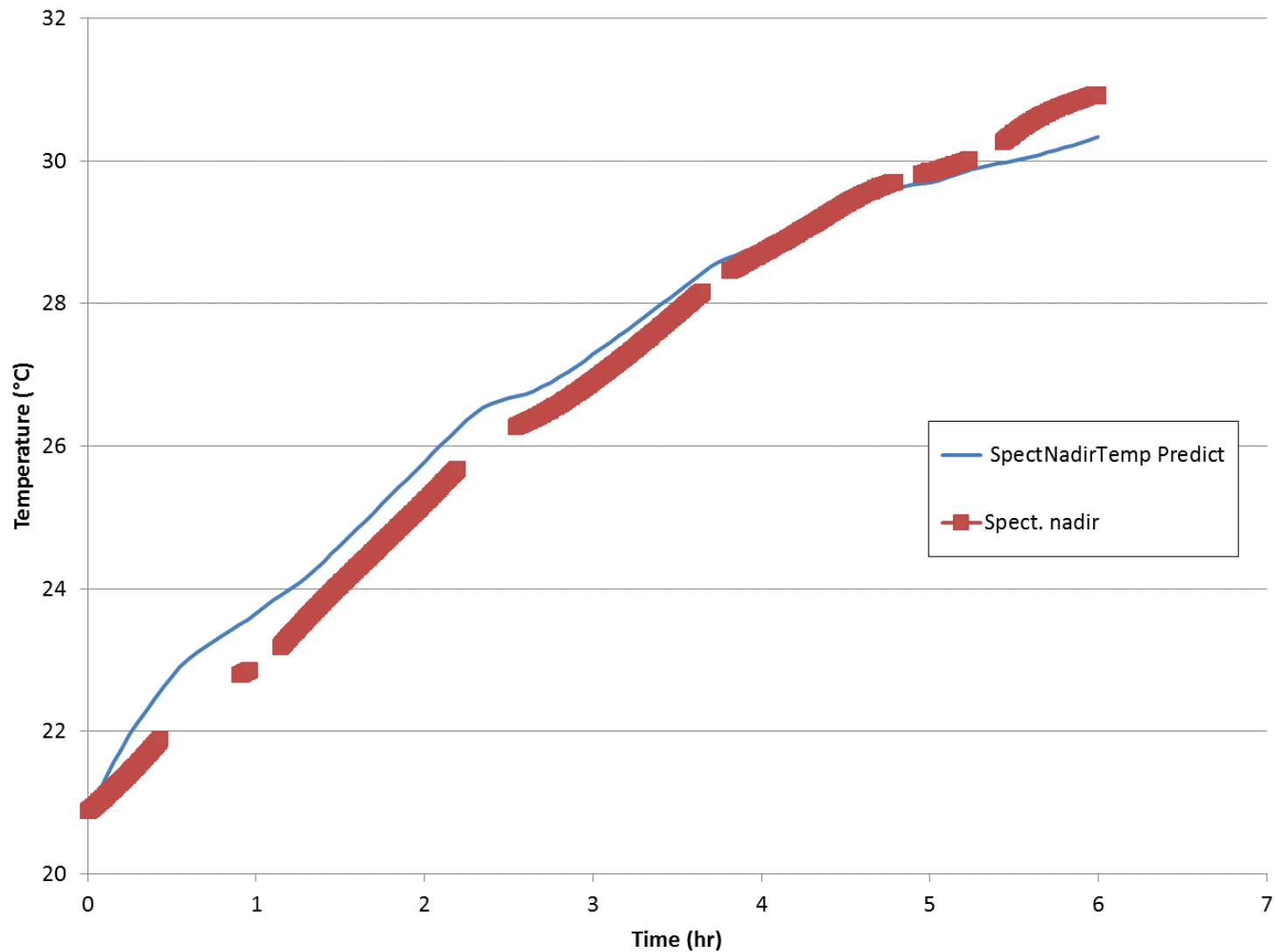


Azimuth Motor Temperature Correlation



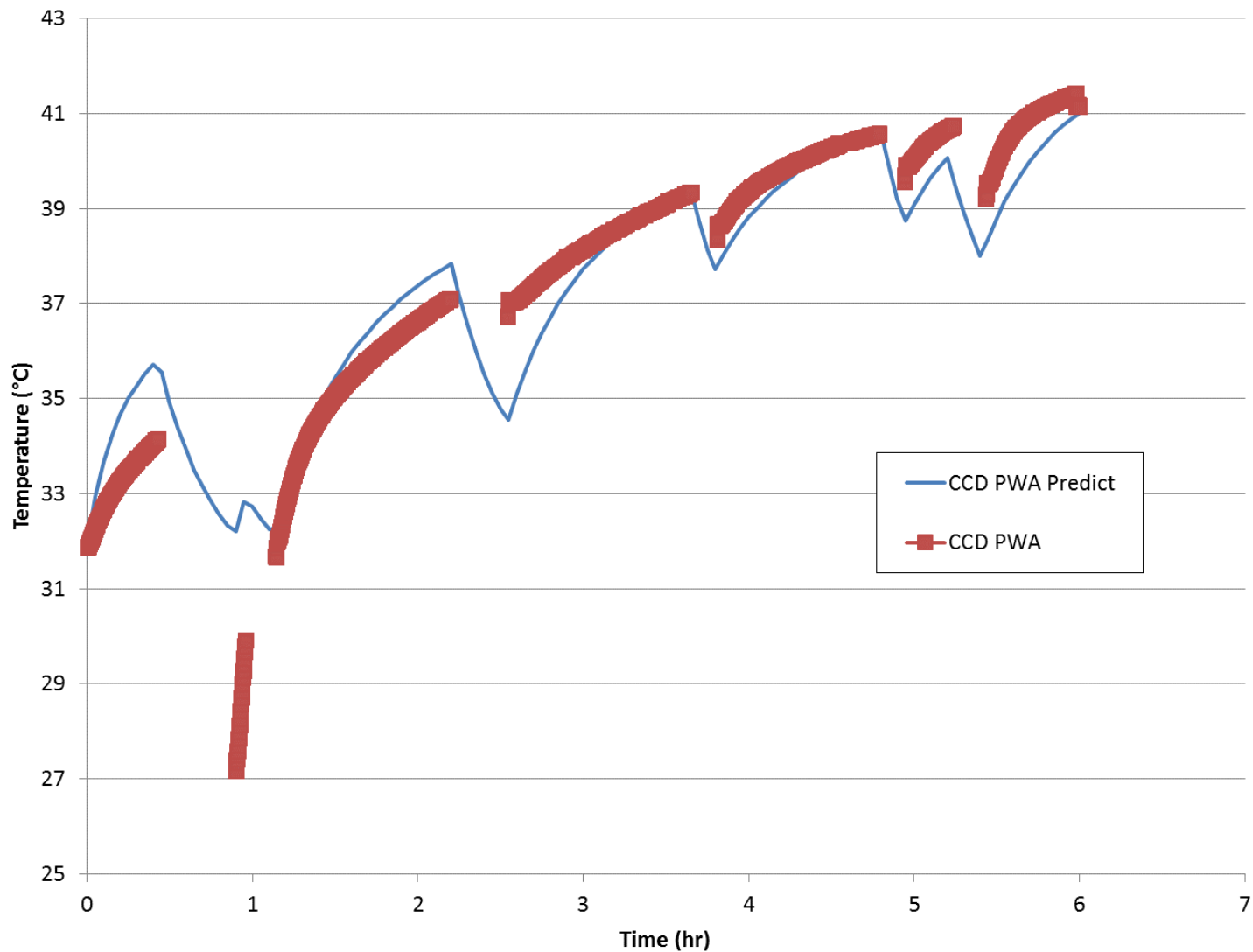


TEC Case1





TEC Case1





TEC Case1

